Test Report

Standard(s): **FCC Part 15**
Class A

Model(s): **SU1 Fuel Cell System**

Prepared for: **Plug Power**
968 Albany-Shaker Road
Latham, NY 12110

Date(s) of test: **May 1, 2001 and May 2, 2001**

Prepared by: _____Date_____

Keith Henderson, Compliance Engineer

Reviewed by: _____Date_____

Michael Koffink, EMI Section Manager

Insert certificate

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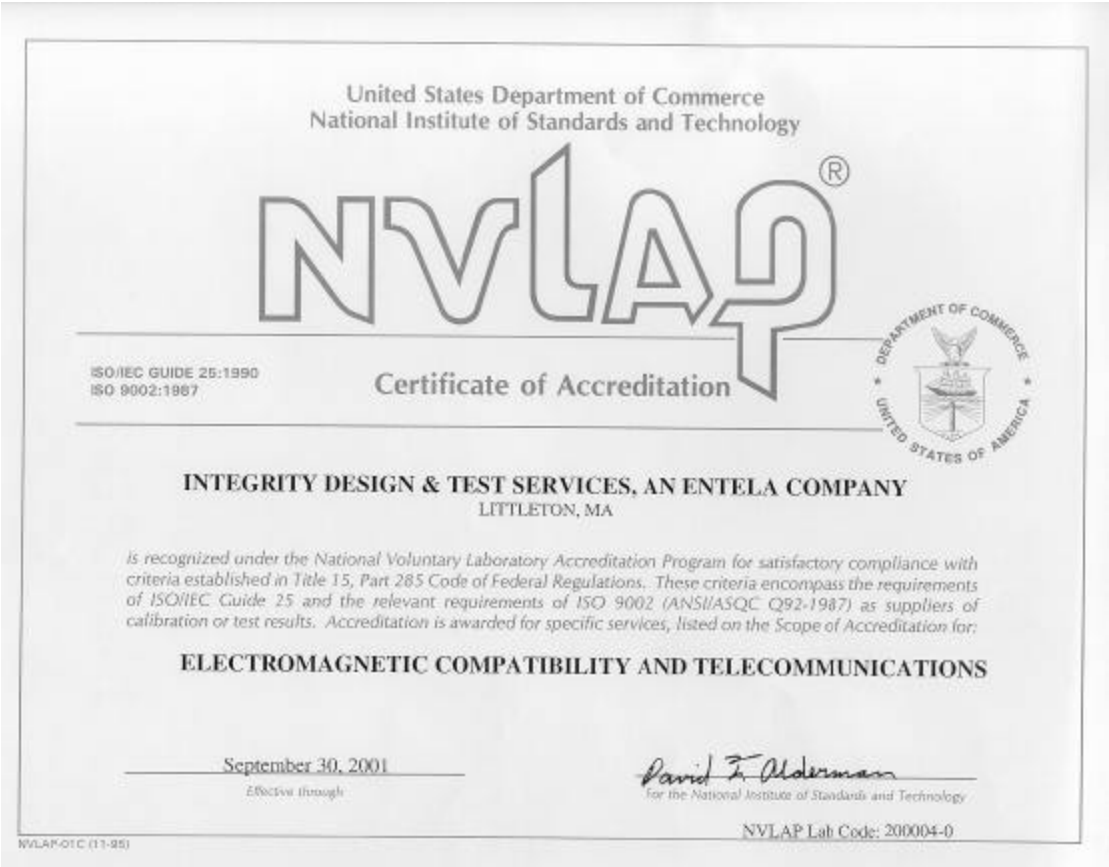

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September 30, 2001
Effective through

David F. Alderman
For the National Institute of Standards and Technology

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List of Tables

1. Executive Summary

1.1 Scope

This document describes electromagnetic emissions testing performed on the SU1 Fuel Cell System on May 1, 2001 and May 2, 2001, pursuant to FCC CFR 47 Part 15. It may be used to demonstrate compliance with the FCC emissions requirements as well as Canadian emissions requirements regulated by Industry Canada as defined in ICES-003 Issue 2, Revision 1.

1.2 Content

Contained herein are the technical descriptions of the equipment under test (EUT) as well as the test methods and results used to verify compliance with the emissions requirements for Information Technology Equipment (ITE), to the above named standards.

1.3 Conclusions

The SU1 Fuel Cell System met the FCC Class A requirements when tested as described herein. (Refer to Test Descriptions & Results in section 3 for a detailed description).

2. Test Environment

2.1 EUT Description

M/N: SU1 Fuel Cell System S/N: 059608

Description: The EUT is a fuel cell power generation system. The system uses a natural gas as a fuel source to create electricity and heat.

2.1.1 System Operation

The system was configured in a typical operation. During testing, the EUT was operating from a natural gas source and delivering 5KW of electrical power to a resistive load bank. The system was controlled from a laptop computer.

2.1.2 Support Equipment:

Description	Manufacturer	Model Number	Serial Number	FCC ID
Laptop computer	Toshiba	P5221U-390J08	5063163U-1	CJ6JPN-40072-M5-E
AC Load Bank	Simplex, Inc.	SWIFT-E F.T.	37961-99-41/18	N/A

Cables

Qty	Description	Cable (Loopback/Open Ended/Connected?)	Unshielded/Shielded Type (Braided/Foil)	Shield Termination (360°/Drain)	Length (Meters)
1	Load bank Cable	Connected to load bank	AC 2 ph. Unshielded	N/A	4
1	RS232 Cable	Connected between fuel cell system and laptop	Shielded	360º	4

2.2 Test Facility Description

The test facility is located on the premises of Integrity Design & Test Services, Inc. at 37-7 Ayer Road, Littleton, MA 01460. All testing is performed in an Open Area Test Site conforming to the site attenuation characteristics defined by ANSI C63.4 1992. Test methods and facilities have been audited and accredited by the National Voluntary Lab Accreditation Program (NVLAP).

2.3 Test Equipment

All equipment used in the testing process have up to date calibrations traceable to the National Institute of Standards and Technology (NIST). Refer to Table 2.3-1 for a complete list of equipment used during the testing.

2.4 Product Disposition

All items received for testing undergo an inspection to ensure proper working condition upon reception and before return shipment. The unit under test passed the incoming inspection when received for testing on May 1, 2001 and May 2, 2001. The unit was returned to the client's facility at the completion of testing after passing the final inspection.

Table 2.3-1: Test Equipment

Description	Model Number	Serial Number	Last Calibration	Due Calibration	EMI #
Spectrum Analyzer (9 KHz to 22 GHz)	HP8593E	3543A01976	7/31/00	7/31/01	145-1
LISN: 50Ω/50µH	91221-1	0386	3/23/01	3/23/02	145-2
Preamplifier (150 KHz to 1.3 GHz)	HP 8447D	2443A04077	5/3/01	5/3/02	145-3
LISN: 50Ω/50µH	Solar 9252-50-R-24-BNC	941725	5/16/00	5/16/01	145-5
BiLog Antenna (30 MHz to 2 GHz)	Chase CBL6112A	2284	7/12/00	7/12/01	145-6
BiLog Antenna (30 MHz to 2 GHz)	Chase CBL6112A	2173	8/10/00	8/10/01	145-7
LISN: 50Ω/50µH	Solar 9252-50-R-24-BNC	971601	6/8/00	6/8/01	145-8
LISN: 50Ω/50µH	Solar 9252-50-R-24-BNC	941724	8/31/00	8/31/01	145-9
Guided Ridged Horn (1 GHz to 18 GHz)	A.H. Systems SAS-200/571	163	10/31/00	10/31/01	145-10
Preamplifier (150 KHz to 1.3 GHz)	HP 8447D	2944A07027	5/4/01	5/4/02	145-13
Preamplifier (1 GHz to 26.5 GHz)	HP 8449B	3008A00232	8/8/00	8/8/01	145-14
LISN: 50Ω/50µH	Solar 9252-50-R-24-BNC	971617	6/21/00	6/21/01	145-15
LISN: 50Ω/50µH	91221-1	0335-04304	3/23/01	3/23/02	145-16
LISN: 50Ω/50µH	3850/2	9606-1052	7/6/00	7/6/01	145-17
LISN: 50Ω/50µH	91221-1	0385	3/23/01	3/23/02	145-18
Preamplifier (1 GHz to 26.5 GHz)	HP 8449B	3008A00948	8/24/00	8/24/01	145-20
Spectrum Analyzer (9 KHz to 26 GHz)	HP 8593EM	3412A00102	12/28/00	12/28/01	145-21
Guided Ridged Horn (1 GHz to 18 GHz)	EMCO 3115	5520	12/7/00	12/7/01	145-29
LISN: 50Ω/50µH	Solar 9233-50-TS-50-N	981960	10/31/00	10/31/01	145-31
Monopole Antenna	AM-541	11008	4/27/01	4/27/02	145-32
Preamplifier (150 KHz to 1.3 GHz)	HP 8447D	2944A08408	2/14/01	2/14/02	145-33

Description	Model Number	Serial Number	Last Calibration	Due Calibration	EMI #
BiLog Antenna (30 MHz to 1GHz)	Chase CBL6111C	2564	5/30/00	5/30/01	145-34
Digital Multi Meter	75 Series II	55400267	6/2/00	6/2/01	145-42
LISN: 50Ω/50µH	9857-50-BP-24-BNC	001139	6/19/00	6/19/01	145-58

All equipment used for testing has been calibrated according to methods and procedures defined by the National Institute of Standards and Technology (NIST).

3. Test Description/Results

3.1 Radiated Emissions

3.1.1 Object

The purpose of this test is to measure the radiated electromagnetic emissions generated by the equipment under test (EUT), pursuant to FCC part 15 Class A requirements. (See Table 3.1.1-1 for the Class A radiated limits).

3.1.2 Procedure

Testing is performed in an Open Area Test Site. The EUT is placed on the center of a turntable. Peripheral equipment is placed on either side of the EUT with a minimum of 10 cm spacing. (When testing a personal computer system, monitors shall be placed on top of the PC, and the keyboard and mouse shall be placed in front of the PC towards the front edge of the turntable.) Excess interface cables are bundled and kept off the ground plane by a insulating sheet of 2 mm thickness.

The EUT shall be set into operation such that all parts of the system are exercised. This may require the use of test software designed to exercise the various parts of the system.
With the EUT set into operation, the turntable is rotated over 360 degrees and interface cables are manipulated to maximize the emissions. The peripherals are not moved during the test. The receiving antenna is placed at a test distance of 3 or 10 meters from the closest point on the EUT. The antenna height is varied from 1 to 4 meters, and the polarity of the antenna is switched between vertical and horizontal such that the received signal is maximized.

3.1.3 Deviations from Test Method

None

3.1.4 Measurement Uncertainty

A minimum of a 2 dB margin of compliance is recommended for radiated emissions data to verify passing results. This is recommended to compensate for the measurement uncertainties involved.

3.1.5 Results

The SU1 Fuel Cell System met the FCC Class A radiated emissions requirements when tested as described below. (See Appendix A for a complete listing of data points).

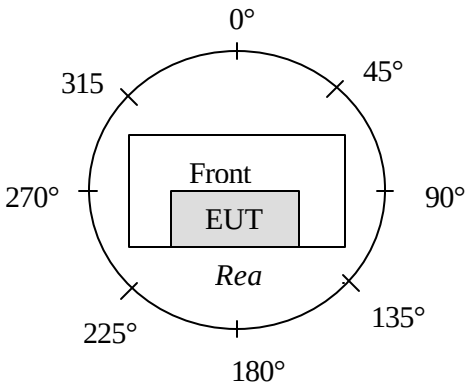
Worst case emissions measured:

Modifications	**FCC Class A Radiated Emissions**
See Note (1)	Passed: - 9 dB at 33.9 MHz Line Voltage: 240 VAC 60 Hz See Table: A1 Azimuth Angle (see diagram below): 90° Antenna Height: 1 meter Polarity: Vertical

Notes

(1) Zippertubing over all signal wires and 48 VDC Auxiliary buss starting at the inverter end and covering about 1 meter of cable running into the fuel cell cabinet.
(2) Steelbraid over the communication wires starting at the inverter end and covering about 1 meter of cable running into the fuel cell cabinet.
(3) Ground strap from the Stack bottom plate to ground.
(4) 3 ferrites added in (Fairrite # 0443164151), 1 on each-fan wires, communication wires, and 24 volt tap. All placed on wires near the inverter.

Azimuth Angle Diagram



The above results pertain only to the specific item submitted for testing, identified by the product's model and serial numbers.

3.1.6 Radiated Emissions Terms and Calculation

The following is a description of terms and a sample calculation, as appears in the radiated emissions data table. The numbers used in the calculation are for example only. There is no direct correlation to the specific data taken for the product described in this document:

Reading: This is the reading obtained on the spectrum analyzer in dBµV. Any external preamplifiers used are taken into account through internal analyzer settings.

A.F.: This is the antenna factor for the receiving antenna. It is a conversion factor, which converts electric fields strengths to voltages, which can be measured directly on the spectrum analyzer. It is treated as a loss in dB. Cable losses have been included with the A.F. to simplify the calculations. The antenna factor is used in calculations as follows:

Reading on Analyzer (dBmV) + A.F. (dB) = Net field strength (dBmV/m)

Net: This is the net field strength measurement (as shown above).

Limit: This is the FCC Class A radiated emission limit (in units of dBµV/m).
The FCC limits are given in units of µV/m. The following formula is used to convert the units of µV/m to dBµV/m:

*Limit (dBmV/m) = 20*log (mV/m)*

Margin: This is the margin of compliance below the FCC limit. The units are given in dB. A negative margin indicates the emission was below the limit. A positive margin indicates that the emission exceeds the limit.

Example for an emission measuring 20.5 dBµV on the spectrum analyzer at 592 MHz:
(Note: This shows a passing result (i.e. a negative margin))

Example only:

Reading		A.F.		Net Reading		Net Reading		FCC limit		Margin
20.5dBµV	+	25 dB	=	45.5 dBµV/m	:	45.5 dBµV/m	-	57 dBµV/m	=	-11.5 dB

3.2 Conducted Emissions

3.2.1 Object
The purpose of this test is to measure the conducted electromagnetic emissions on the AC power lines, pursuant to FCC part 15 Class A requirements. (See Table 3.2.1-1 for the Class A conducted limits).

3.2.2 Procedure
Testing is performed in an Open Area Test Site. Equipment is arranged as described in section 3.1.2. Each individual current-carrying power lead shall be individually connected through a 50Ω/50µH Line Impedance Stabilization Network (LISN). The EUT is set into operation such that all parts of the system are exercised, while the RF voltages across the 50 Ω measuring port of the LISN are recorded. The test is repeated for each current-carrying power line of the EUT.

3.2.3 Deviations from Test Method
None

3.2.4 Measurement Uncertainty
A minimum of a 1 dB margin of compliance is recommended for conducted emissions data to verify passing results. This is recommended to compensate for the measurement uncertainties involved.

3.2.5 Results

The SU1 Fuel Cell System met the FCC Class A conducted emissions requirements when tested as described below. (See Appendix A for a complete listing of data points).

Worst case emissions measured:

Modifications	**FCC Class A Conducted Emissions**
See Note (1)	Passed: - 12.3 dB at 0.48 MHz Line Voltage: 240 VAC 60 Hz See Table: A3

Notes

(1) A corcom filter # 63ADT6 was inserted.

The above results pertain only to the specific item submitted for testing, identified by the product's model and serial numbers.

3.2.6 Conducted Emissions Terms and Calculation

The following is a description of terms and a sample calculation, as appears in the conducted emissions data table. The numbers used in the calculation are for example only. There is no direct correlation to the specific data taken for the product described in this document:

Reading: This is the reading obtained on the spectrum analyzer in dBµV. Any external attenuators used are taken into account through internal analyzer settings.

Limit: This is the FCC Class A conducted emission limit (in units of dBµV).
The FCC limits are given in units of µVolts. The following formula is used to convert the units of µVolts to dBµVolts:

*Limit (dBmV) = 20*log (mV)*

Margin: This is the margin of compliance below the FCC limit. The units are given in dB. A negative margin indicates the emission was below the limit. A positive margin indicates that the emission exceeds the limit.

Example for an emission measuring 55 dBµV on the spectrum analyzer at 5.4 MHz.
(Note: This shows a passing result (i.e. a negative margin))

Example only:

Reading		FCC limit		Margin
55 dBµV	-	60 dBµV	=	-5 dB

Table 3.1.1-1: FCC Class A Radiated Emissions Limit

Frequency	FCC Class A Quasi-Peak (dBmV/m)	
(MHz)	3m	10m
30 to 88	50	39
88 to 216	54	44
216 to 230	57	46
230 to 960	57	46
960 to 1000	60	50
Above 1000	*60	*50

* Average detector used.

Table 3.2.1-1: FCC Class A Conducted Emissions Limit

Frequency (MHz)	FCC Class A Quasi-Peak Limit (dBmV)
.450 to 1.7	60
1.7 to 30	69.5

(Note: For each table shown above, the stricter limit applies at the frequency transition points.)

3.3 Labeling Requirements

3.3.1 FCC Labeling (taken from FCC CFR 47 section 15.19)

A compliance label similar to the following must be affixed to the product pursuant to FCC part 15 Class A requirements:

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Information to user (taken from FCC CFR 47 section 15.105)

For a Class A digital device or peripheral, the instructions furnished the user shall include the following or similar statement, placed in a prominent location in the test of the manual.

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses , and can radiate radio frequency energy and , if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful Interference in which case the user will be required to correct the interference at his own expense.

In addition to the above statement, the users manual shall caution the user that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment. (Taken from FCC CFR 47 section 15.21).

3.3.2 Industry Canada Labeling (pursuant to ICES-003 Issue 2, Revision 1)

The following is the suggested text for the Canadian product label for ITE equipment. Although the wording may be combined with the FCC label, it must clearly state the equipment meets the Canadian Interference-Causing Equipment Regulations. (Ref. EMCAB-3 Issue 2)

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

OR

Cet appareil numérique de la classe A respecte toutes les exigences du Règlement sur le matérial brouilleur du Canada.

Please note that Industry Canada requirements state that the label must be in French or English, (the two official languages of Canada).

Appendix A – Test Data

Table A1: FCC Class A Radiated Emissions.

Company: Plug power
Test Engineer: Dan Alvarez/George Cooper
Model: RU1 Fuel cell system
Test Date: 5-1-01
OATS # 2
Test Configuration: Final Scan (240 VAC, 60 Hz)

Polarity (V or H)	Frequency (MHz)	Reading (dB_u V)	A.F. (dB)	Net (dB_u V/m)	FCC Class A Limit @3m (dB_u V/m)	Margin (dB)
V	31.3	21.5	17.5	39	50	-11
V	33.9	24.5	16.5	41	50	-9
V	36.4	14.5	16.5	31	50	-19
V	62.4	22	8	30	50	-20
V	64.5	26	8	34	50	-16
V	68.9	22	8	30	50	-20
V	72.1	24.5	8	32.5	50	-17.5
V	75.7	18	8.5	26.5	50	-23.5
V	83.2	25	10	35	50	-15
V	107.6	3.94	13.5	17.44	54	-36.56
V	117.7	9.6	14	23.6	54	-30.4
V	127.6	8.64	13	21.64	54	-32.36
V	156.5	11.6	12	23.6	54	-30.4
V	167	9.26	12	21.26	54	-32.74
V	177	12.5	12	24.5	54	-29.5
H	188	16.6	12	28.6	54	-25.4
H	231	15.1	13	28.1	57	-28.9
V	260	11.2	16	27.2	57	-29.8
V	300.7	12.5	16.5	29	57	-28
V	380.7	9.4	18	27.4	57	-29.6
V	408.9	11.4	19.5	30.9	57	-26.1
V	579.9	8	23	31	57	-26
V	601	6.7	23	29.7	57	-27.3
V	771.2	13.4	24.5	37.9	57	-19.1

Table A2: FCC Class A Conducted Emissions.

Company: Plug power
Test Engineer: Keith Henderson
Model: RU1 Fuel cell system
Test Date: 5-2-01
OATS # 2
Test Configuration: Final Scan (240 VAC, 60 Hz)

Frequency (MHz)	Phase 1 Reading (dB*u* V)	FCC Class A Quasi-Peak Limit (dB*u* V)	Margin (dB)
0.49	46.1	60.0	-13.9
2.23	30.28	69.5	-39.2
3.83	37.6	69.5	-31.9
5.45	39.47	69.5	-30.0
10.5	20.2	69.5	-49.3
0.91	20.8	60.0	-39.2
25.4	22.4	69.5	-47.1
Frequency (MHz)	**Phase 2 Reading (dB*u* V)**	**FCC Class A Quasi-Peak Limit (dB*u* V)**	**Margin (dB)**
0.49	46.3	60.0	-13.7
1.18	32.2	60.0	-27.8
4.27	30.3	69.5	-39.2
5.31	39.8	69.5	-29.7
9.39	21	69.5	-48.5
14.9	18.6	69.5	-50.9
20	192	69.5	122.5
25	24.6	69.5	-44.9

Table A3: FCC Class A Conducted Emissions.

Company: Plug power
Test Engineer: Keith Henderson
Model: RU1 Fuel cell system
Test Date: 5-2-01
OATS # 2
Test Configuration: Final Scan (240 VAC, 60 Hz)

Frequency (MHz)	Neutral Reading (dBu V)	FCC Class A Quasi-Peak Limit (dBu V)	Margin (dB)
0.48	47.7	60.0	-12.3
1.35	33	60.0	-27.0
2.69	31	69.5	-38.5
5.39	39.1	69.5	-30.4
7.25	29.1	69.5	-40.4
12.23	19.54	69.5	-50.0
19	18.8	69.5	-50.7
25.8	22.6	69.5	-46.9

Configuration Photographs

37-7 Ayer Road *Littleton, MA 01460*
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Configuration Photograph

Company: Plug Power
Model: SU1 Fuel Cell

Worst Case Radiated Emissions Test Configuration

Configuration Photograph

Company: Plug Power
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Worst Case Radiated Emissions Test Configuration

Configuration Photograph

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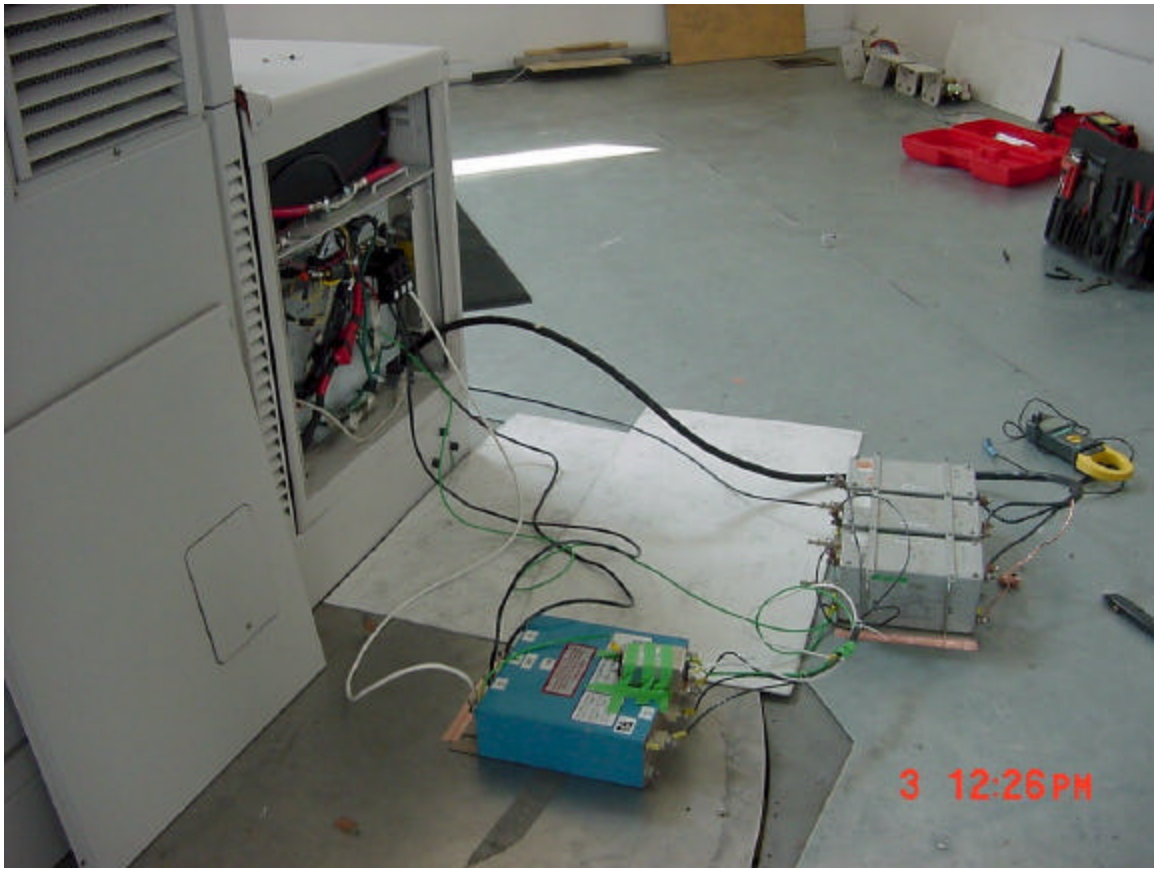

Worst Case Conducted Emissions Test Configuration

Configuration Photograph

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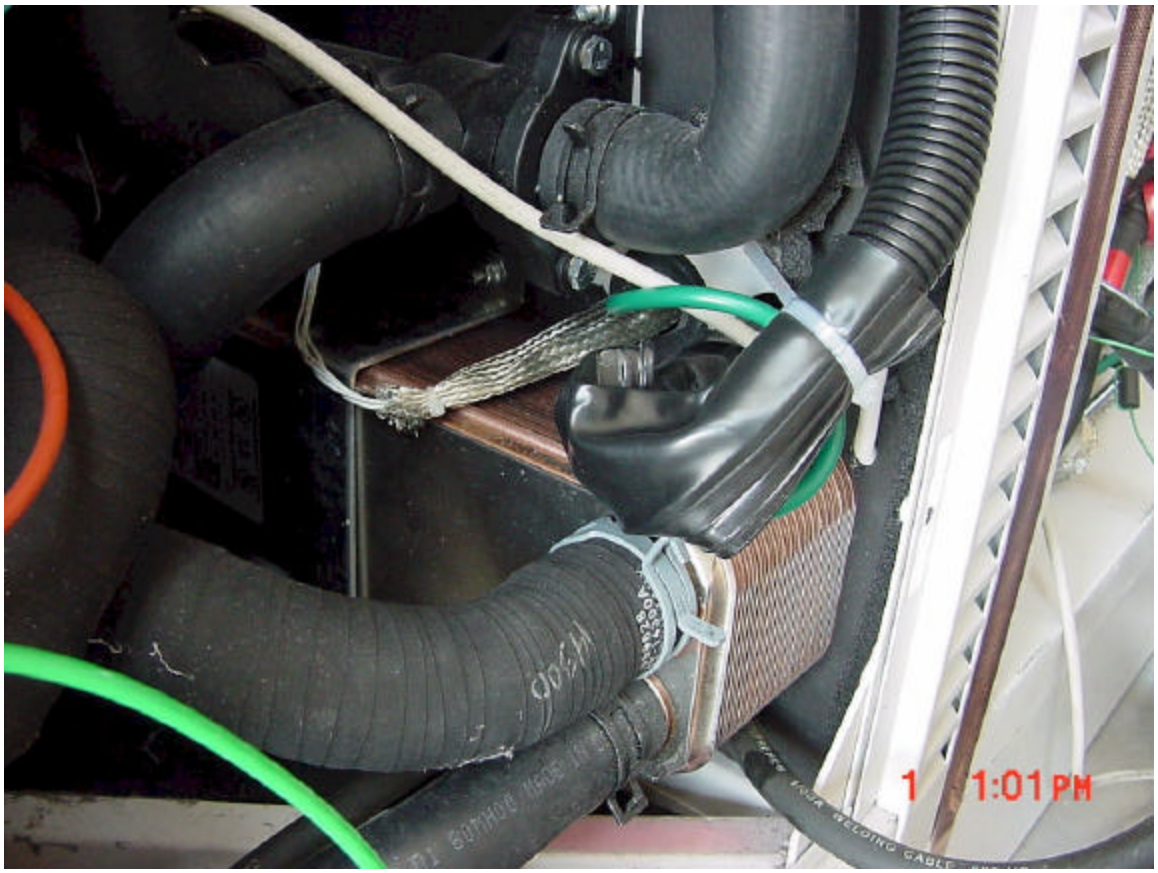

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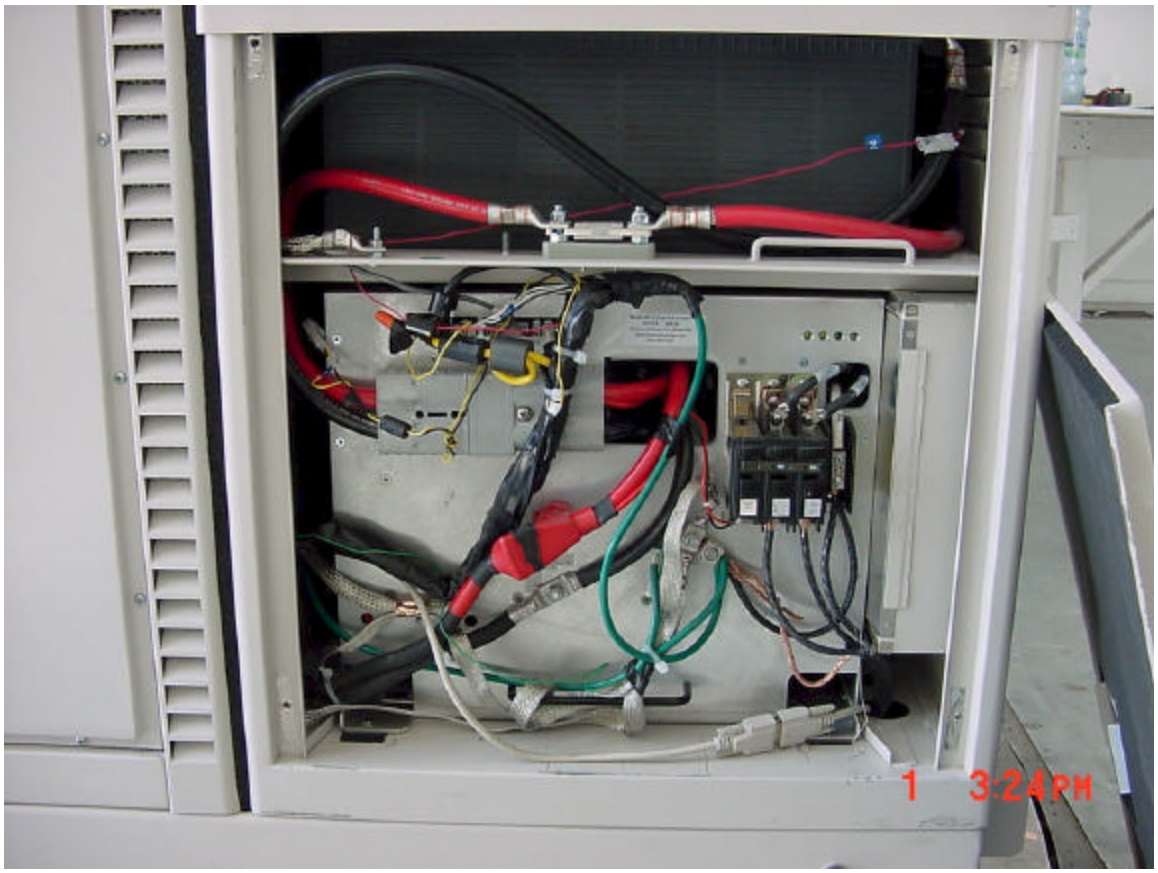

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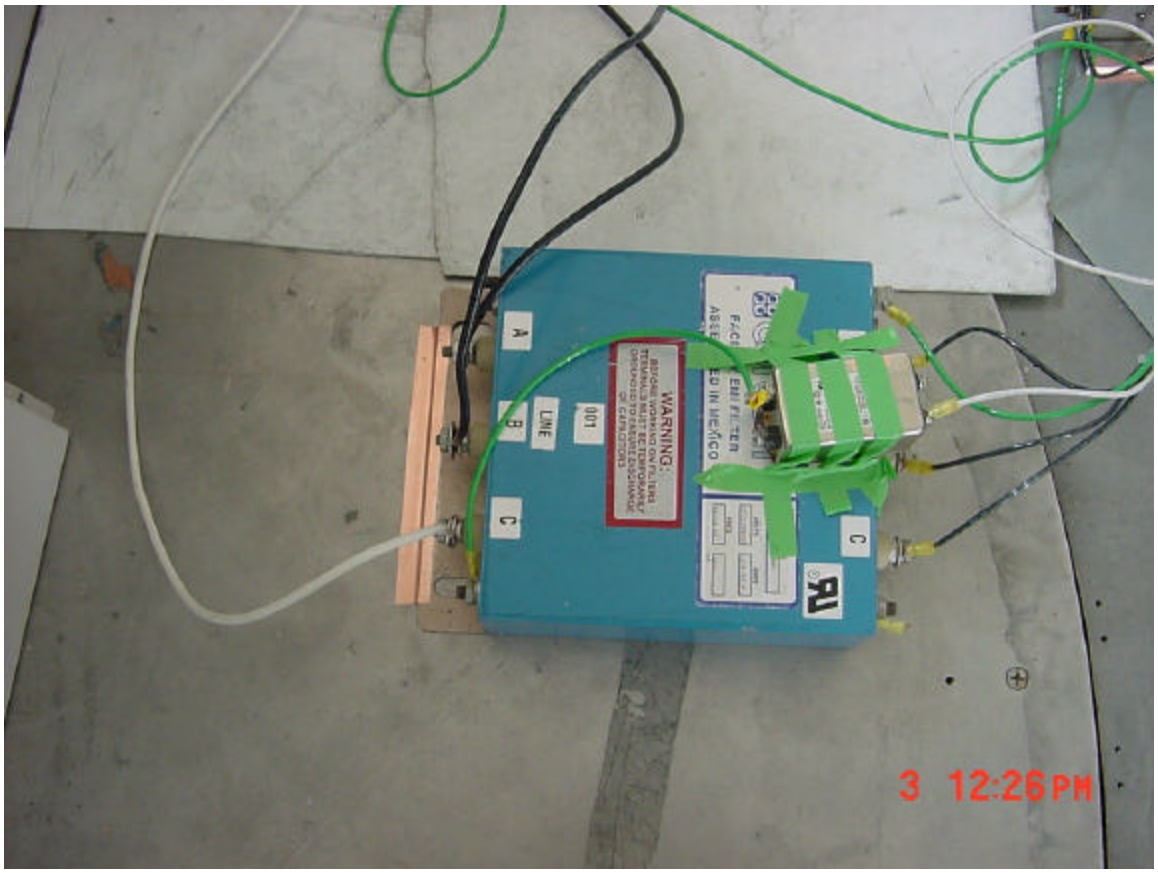

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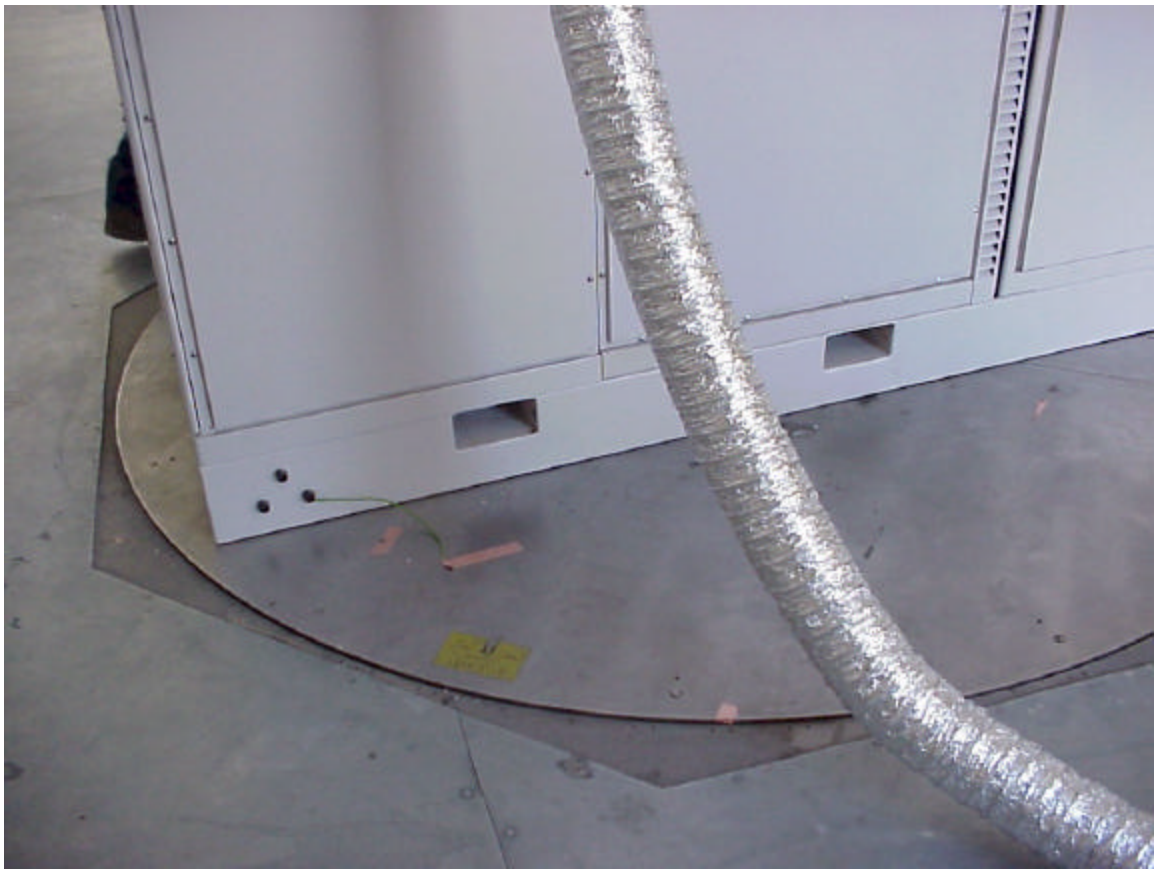

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